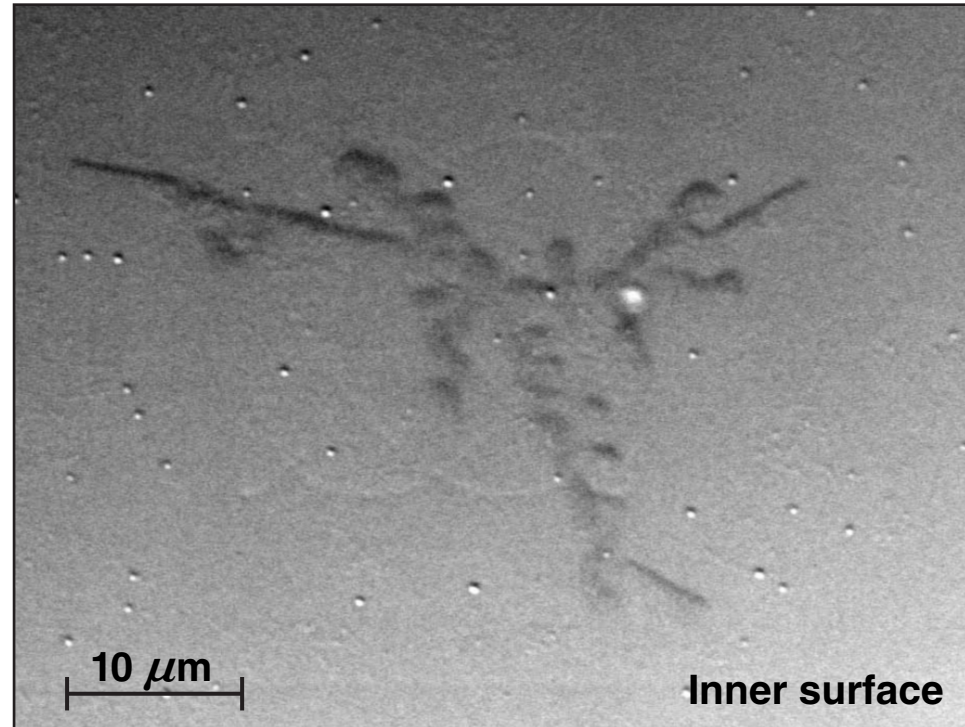
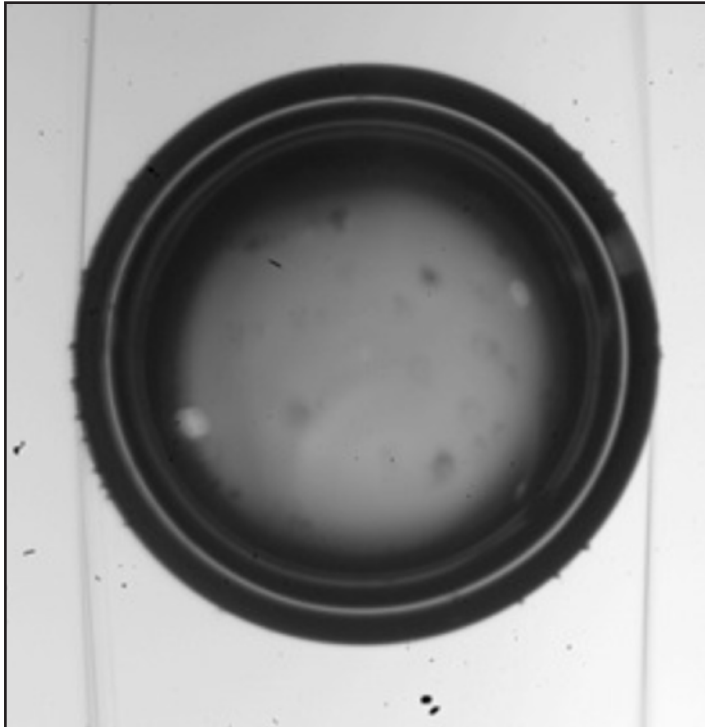


# Mitigating Defects on Cryogenic Targets



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## Summary

# Cryogenic targets can suffer from three types of imperfections: condensates, dendrites, and particulates



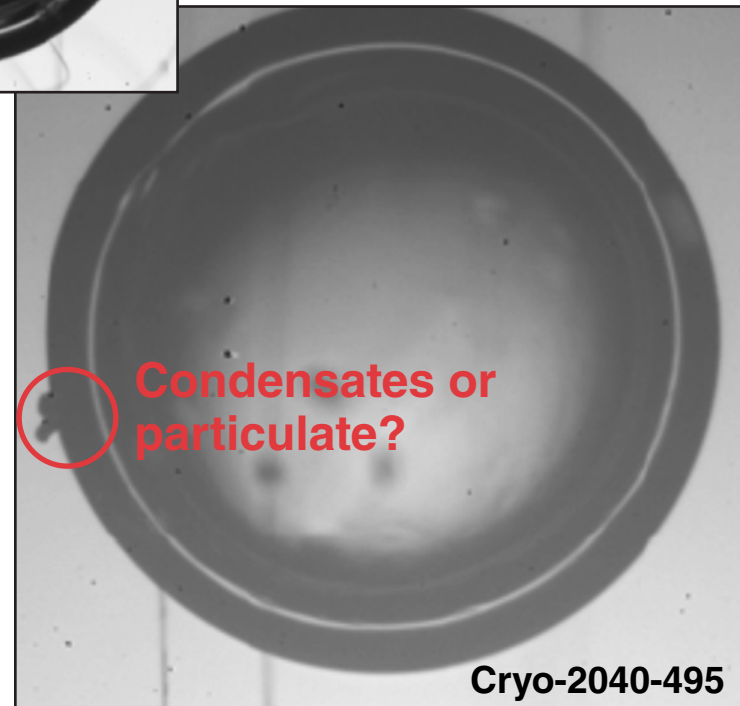
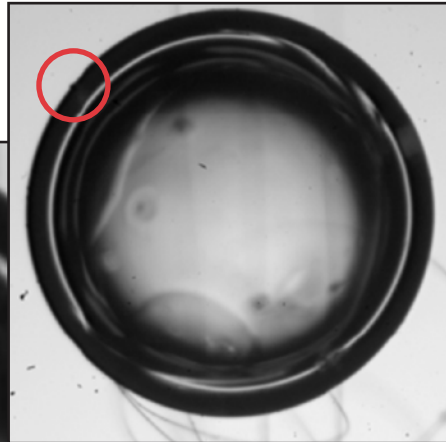
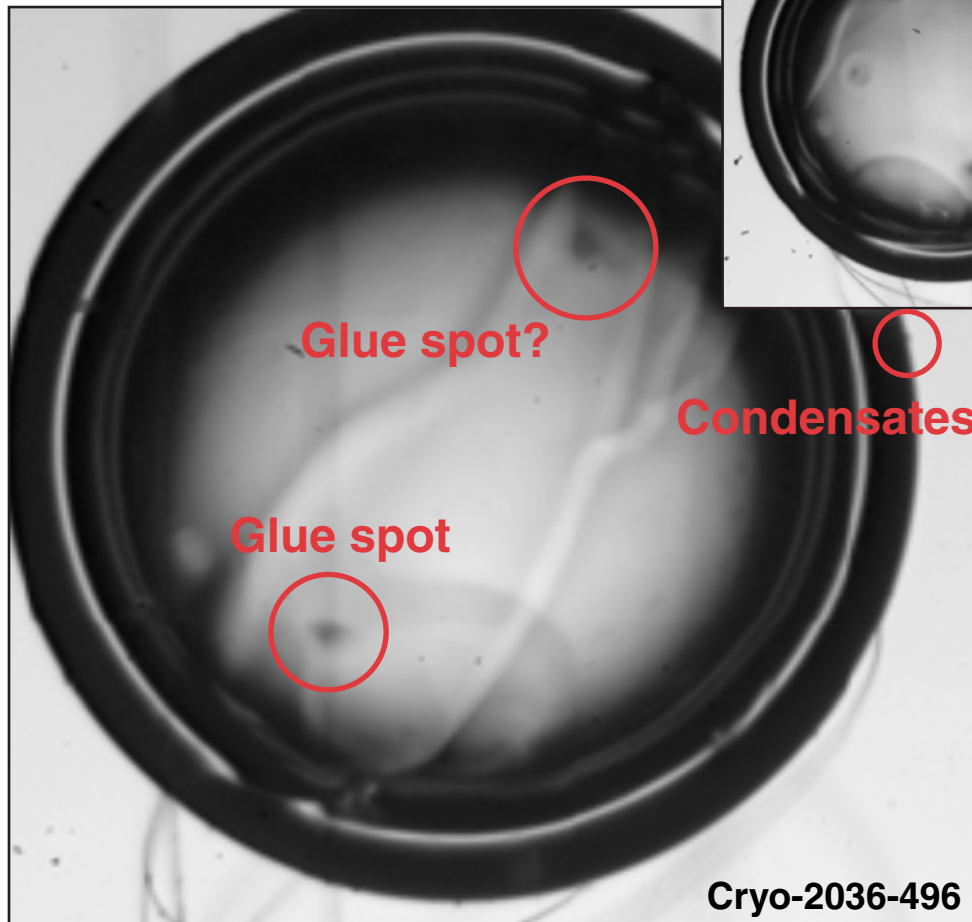
- **Condensates are droplets of impurities that have collected and frozen on the outer surface**
  - condensate formation is minimized by reducing the amount of gas phase contamination
- **Dendrites have a snowflake-like appearance**
  - they are stress-induced tears in the inner surface of the radiation-damaged plastic shells
  - dendrite formation appears to be eliminated by reducing the time cold targets spend in an environment without exchange gas
- **Cryotargets self-charge and can collect debris electrostatically**
  - the cryostat must approach clean room conditions

**Progress has been made in understanding and controlling imperfections on targets.**

# Target defects have been present since the first DT cryogenic targets were formed

2/10/06, Fill #101

0.12% T/D

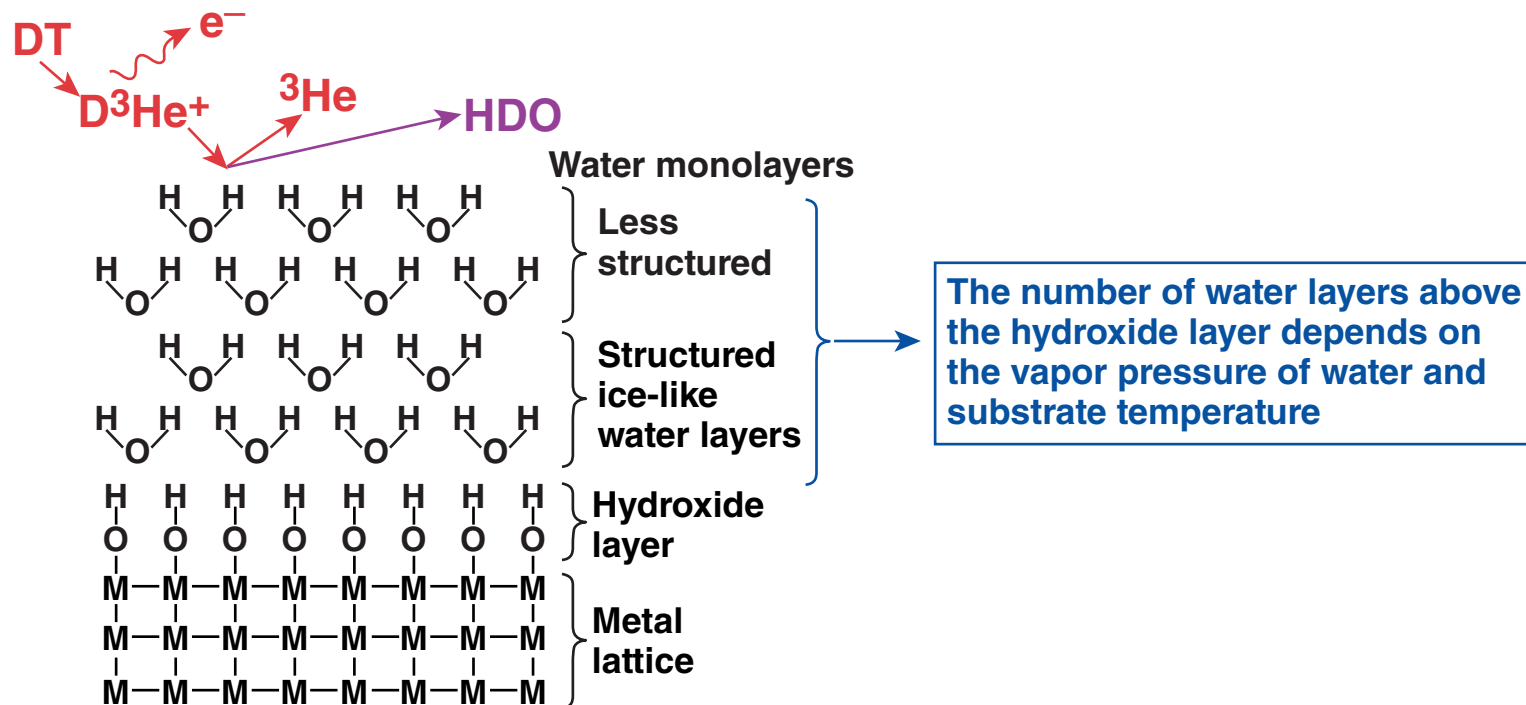


# There are several sources for isolated target nonuniformities

- Gas-entrained contaminants
  - Helium exchange gas at 1 ppb
    - $30 \text{ mTorr} \times 10 \text{ L/s} \times 30 \text{ h} \Rightarrow 42 \text{ sL} \Rightarrow 10^{15} \text{ water molecules}$
  - D<sub>2</sub> operations in the tritium fill system
    - $5 \mu\text{mol}$ : Ar, N<sub>2</sub>
    - $2 \mu\text{mol}$ : H<sub>2</sub>O
    - $1 \mu\text{mol}$ : CO, CO<sub>2</sub>, O<sub>2</sub>, CH<sub>4</sub>
    - $8 \text{ sL} \Rightarrow 2 \times 10^{17} \text{ argon}$
- Atomic hydrogen scavenging of hydroxyls from the inner surfaces of metal process lines
- Decay beta scissions of shell plastic
- Electrostatic attraction of debris (shell fragments, dust, ...)

**$10 \mu\text{m}^3 \text{ crystallite} \leadsto 10^{14} \text{ molecules}$**

# Atomic hydrogen is an efficient scavenger of hydroxyls from metal surfaces to form water vapor

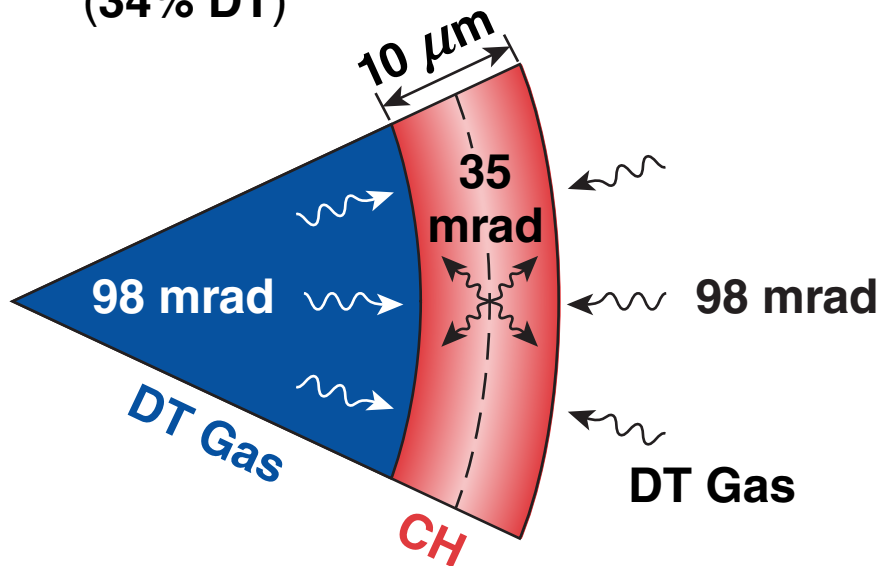


1 hydroxyl every  $3\text{\AA}$   $\rightarrow$   $10^{15}$  water molecules/cm<sup>2</sup>

# Volatile low-molecular-weight organic species are formed when decay betas sever methyl groups in the plastic

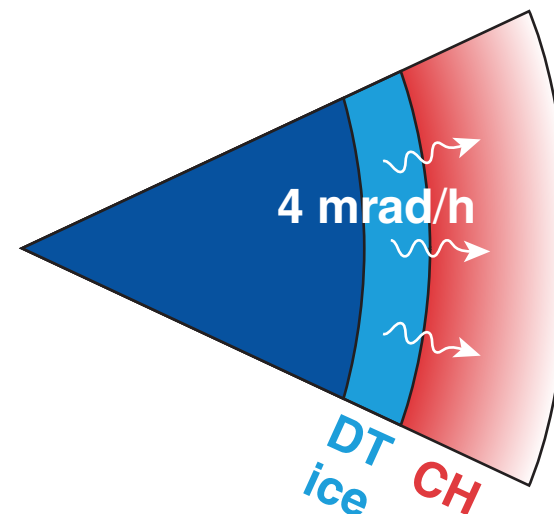


Gas filling and cooling ~30 h  
(34% DT)



Volatile is mobile

Layer formation and maintenance  
120 ↔ 200 mrad



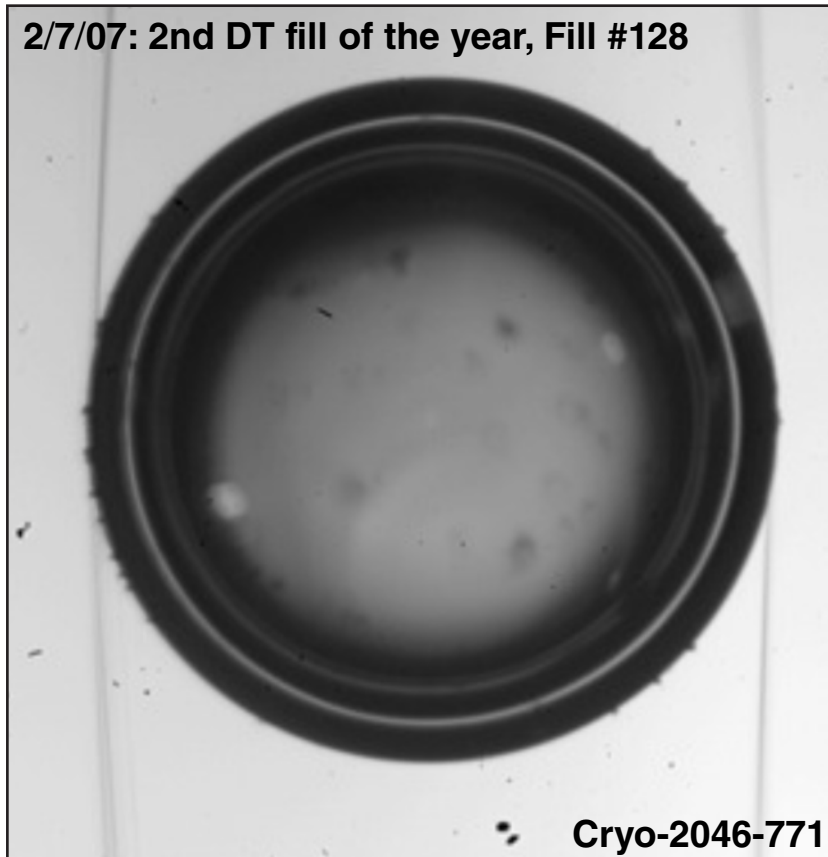
Volatile is frozen

- Typical methane yields for  $\gamma$ -irradiated plastic ~70 nmol/g-mrad
- Methane production from a typical OMEGA target during a gas fill  $\sim 10^{12} \rightarrow 10^{14}$  molecules

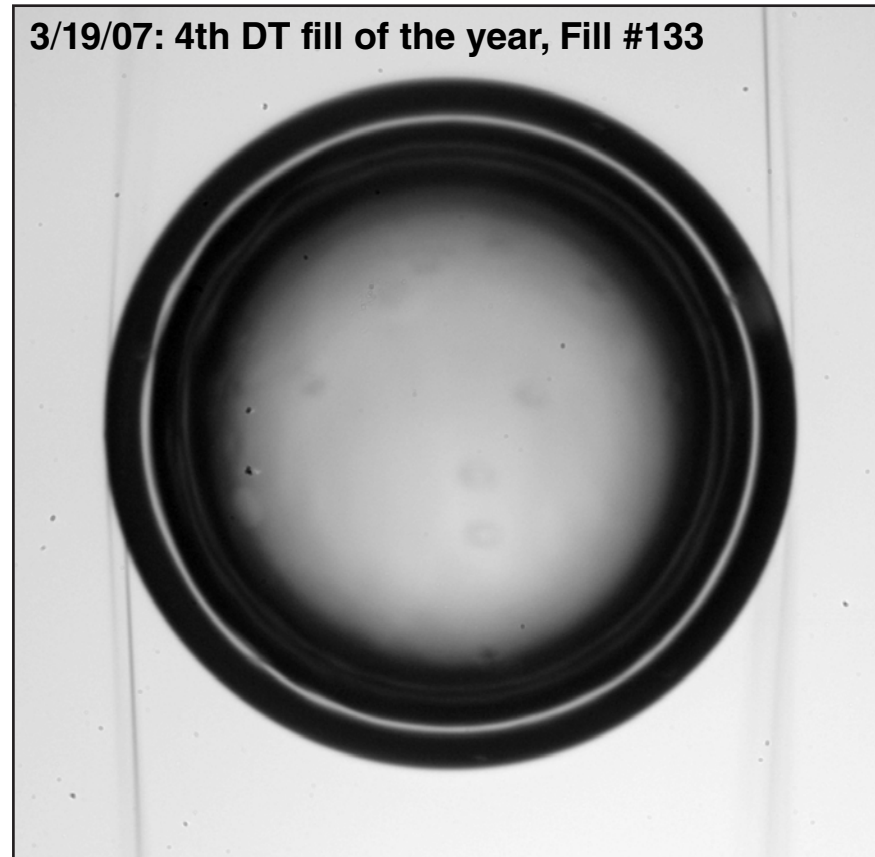
# Condensates arising from gas contamination persist for several fills

- 1/12/07: D<sub>2</sub> used to test pressure ramps
- 1/30/07: 1st fill of the year had an ice plug in sealing gas line

2/7/07: 2nd DT fill of the year, Fill #128



3/19/07: 4th DT fill of the year, Fill #133



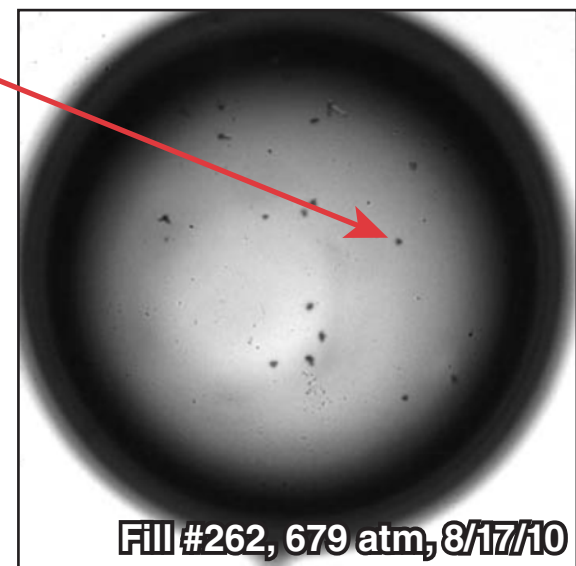
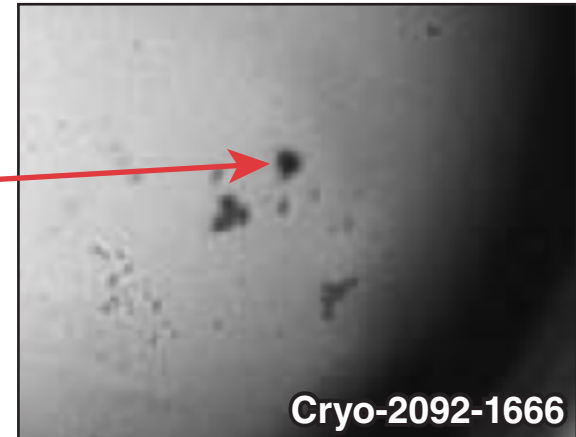
**Most likely argon, possibly H<sub>2</sub>O**

# The character of the condensates suggests different gas species are condensing on the targets

Condensates

?

?



# Some impurities condense on the target surface around 12 K and evaporate by 19 K at specific locations

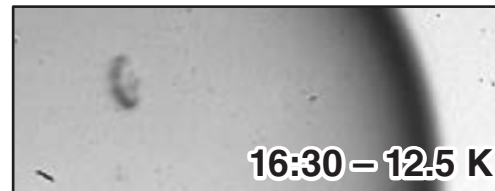


**Cryo-2102-1492**

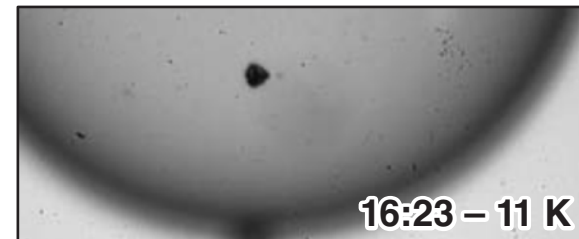
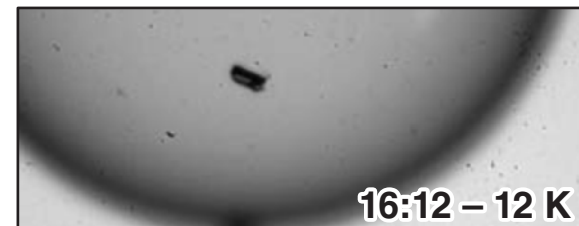
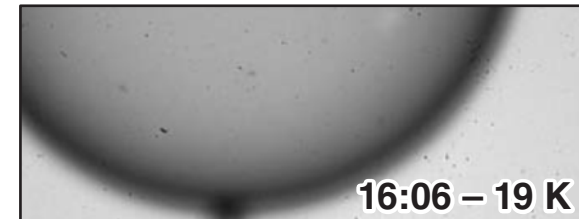


**Fill # 263: mock fill,  
no DT from U-beds  
9/1/10**

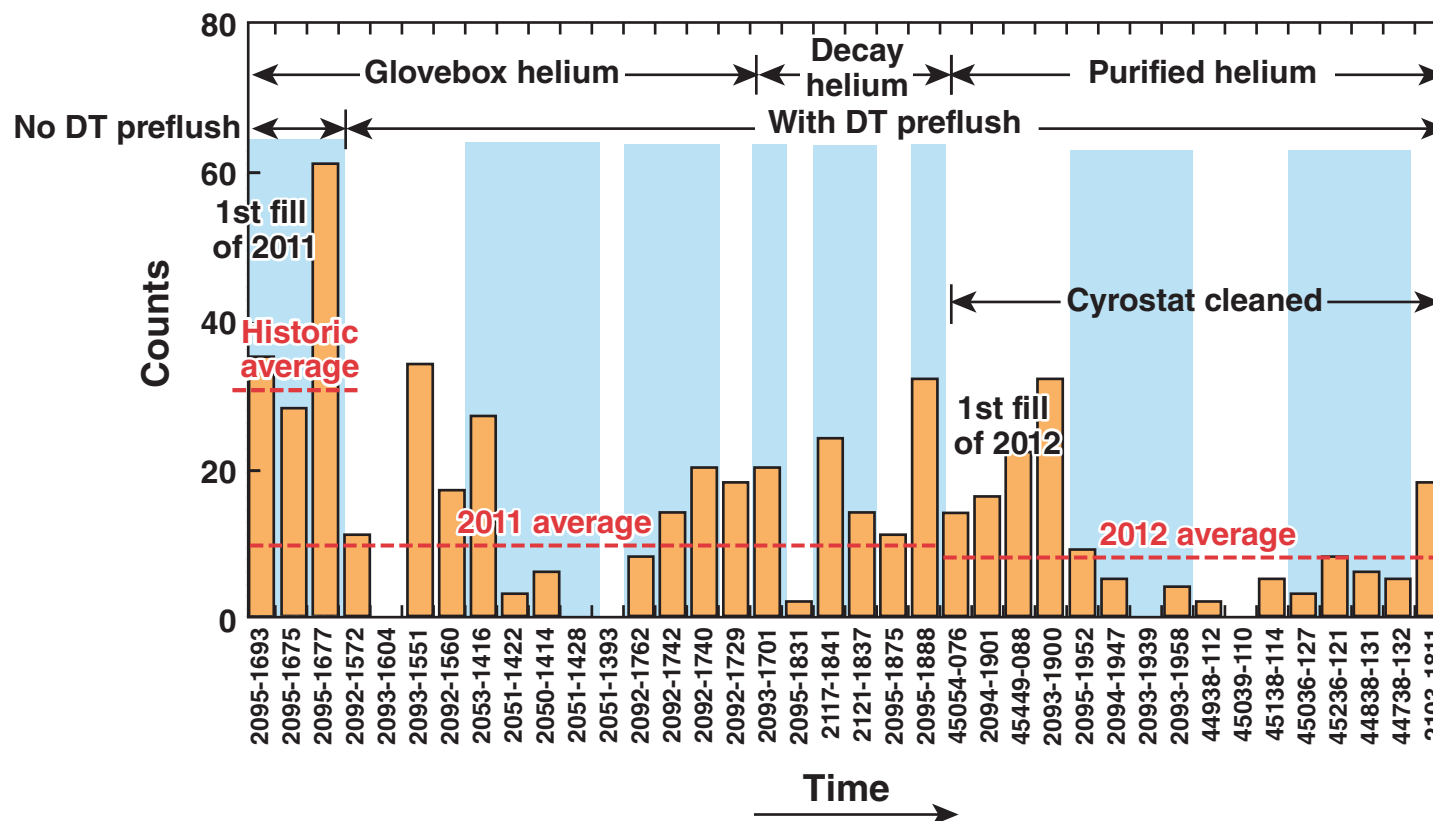
**Cryo-2102-1492**



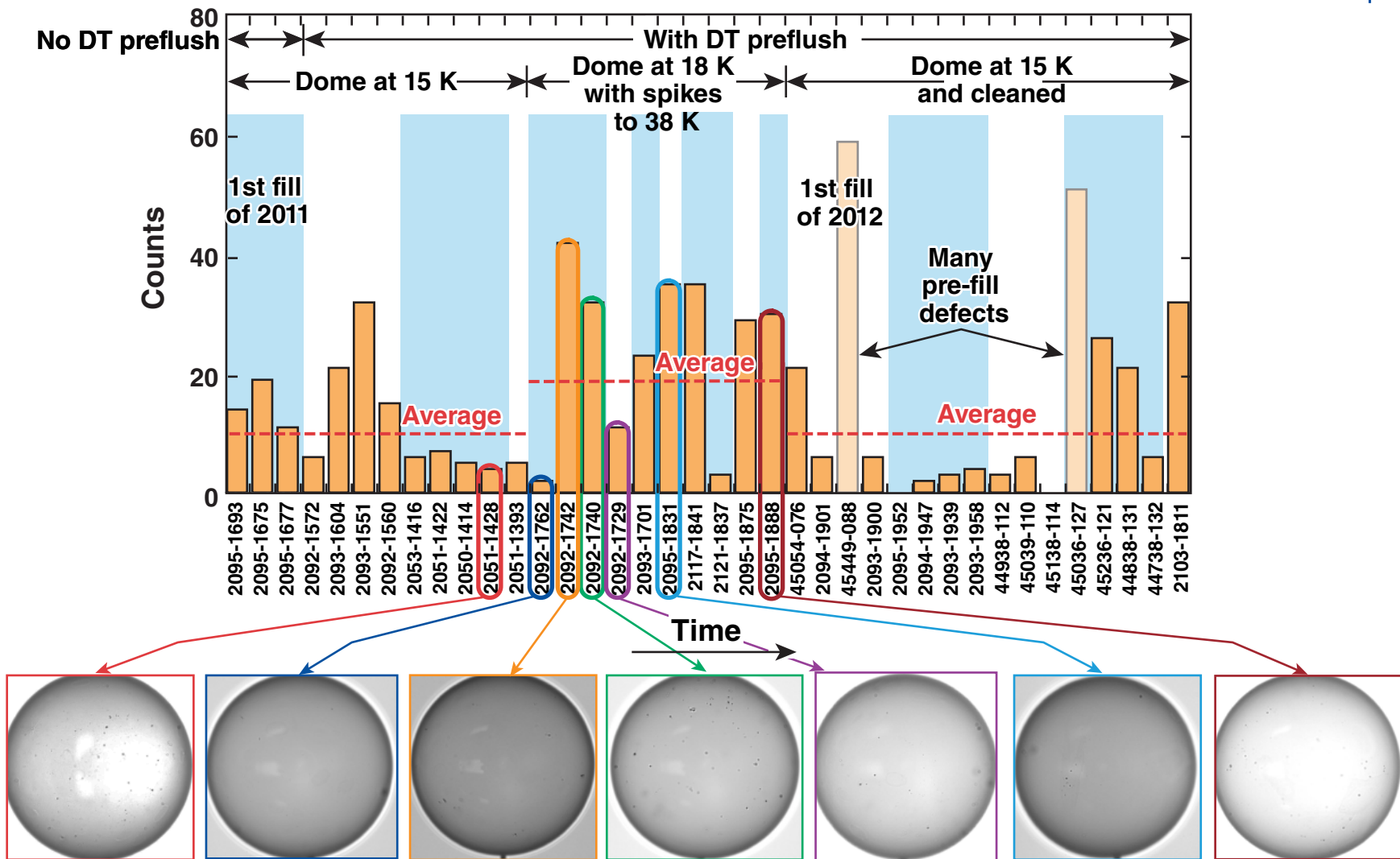
**Cryo-2105-1489**



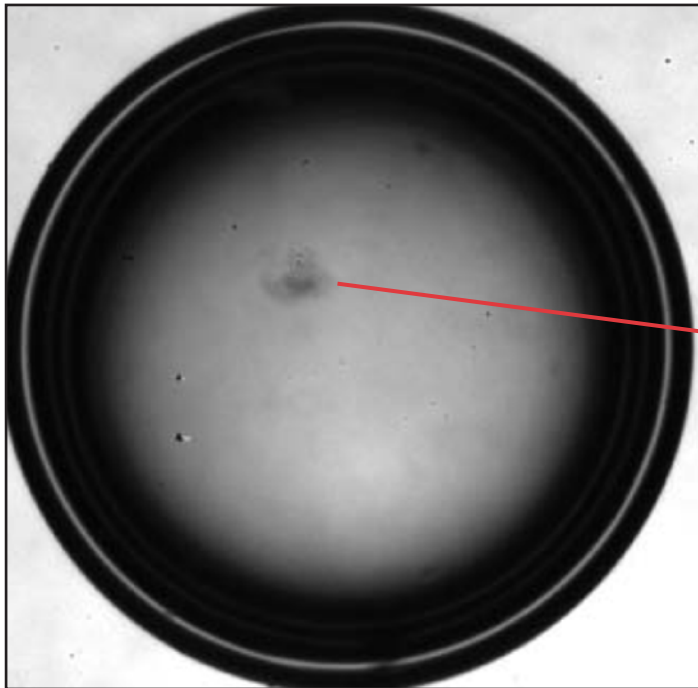
# A DT pre-flush has been effective at reducing the number of condensates with larger surface areas ( $>140 \mu\text{m}^2$ )



# Small defects on pre-filled targets appear to provide nucleation centers for condensates ( $20 \mu\text{m}^2$ and $140 \mu\text{m}^2$ )

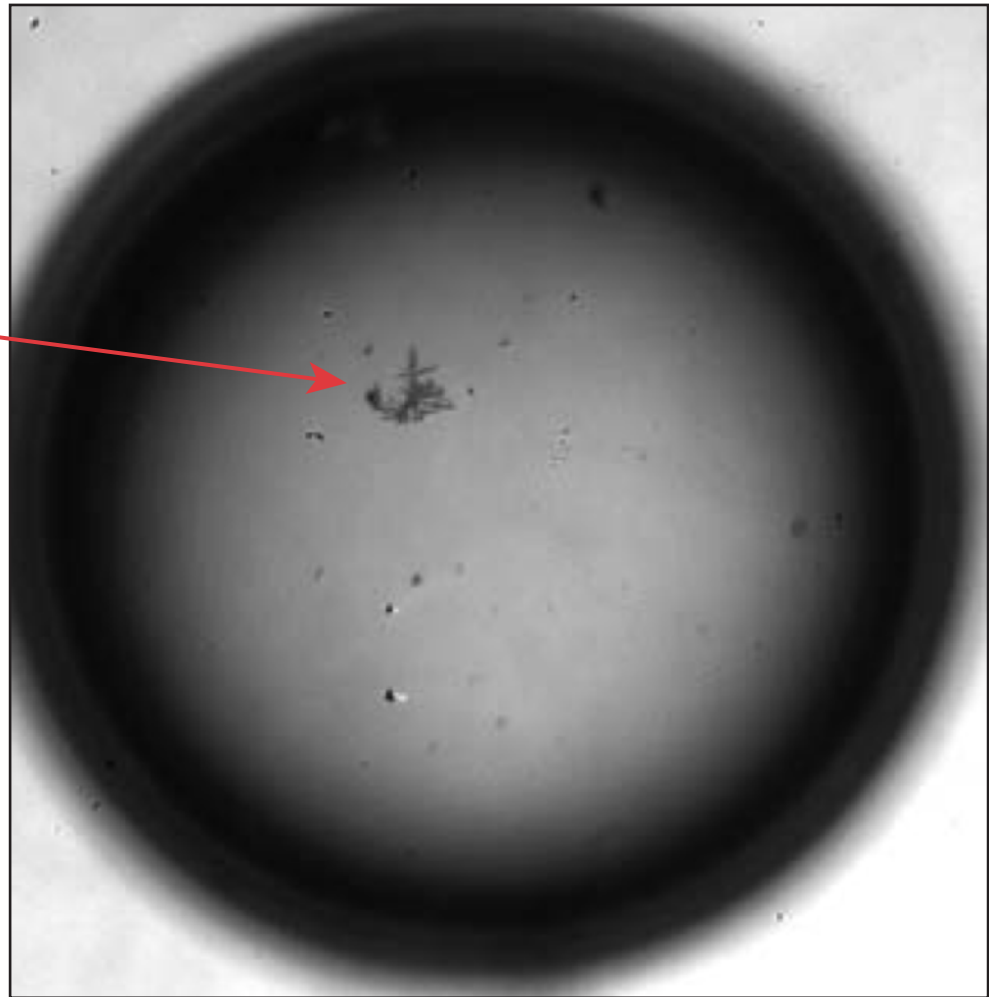


## Dendritic features have been present on targets for all high-activity cryogenic DT fills carried out at LLE

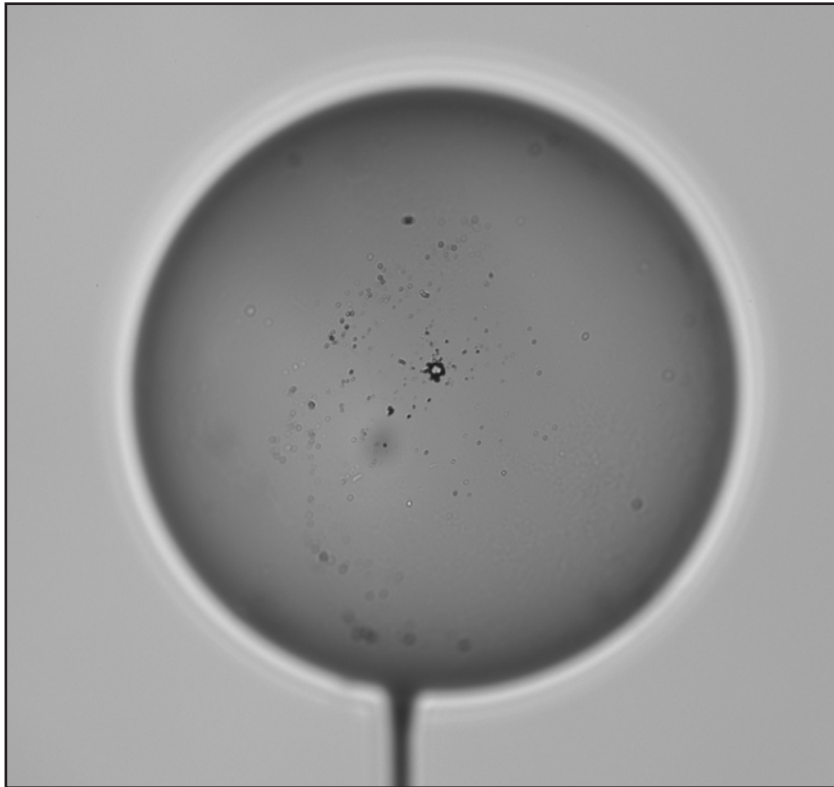


**Dendrites do not develop  
on D<sub>2</sub> filled targets**

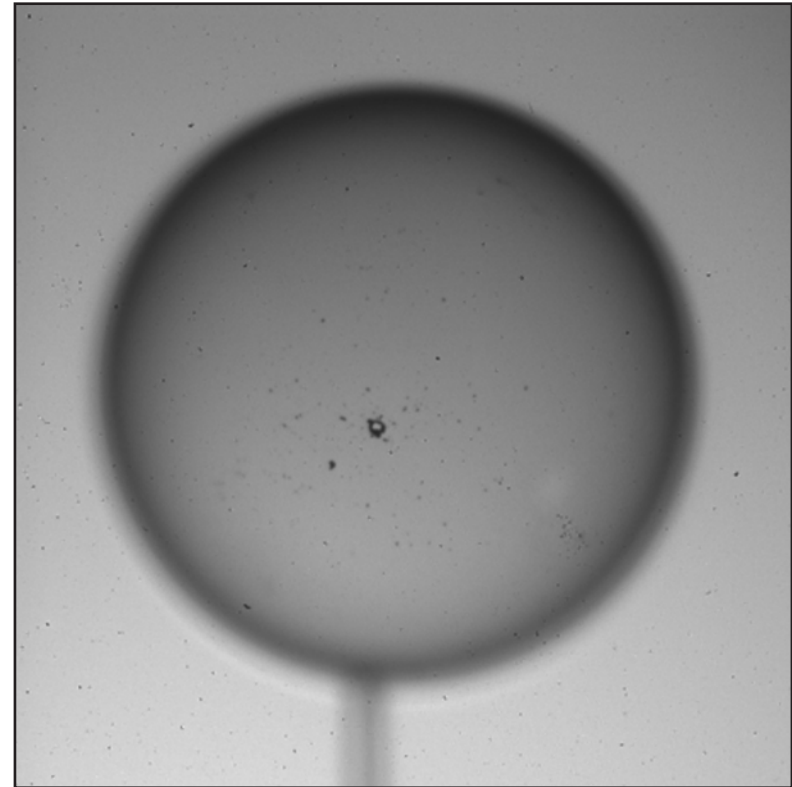
**Fill #258, 679 atm, 6/2/10  
Cryo-2094-1633, 7/23/10**



# A target predrilled with a hole that experienced a complete DT-fill cycle did not develop dendritic defects



**Pre-fill defects**

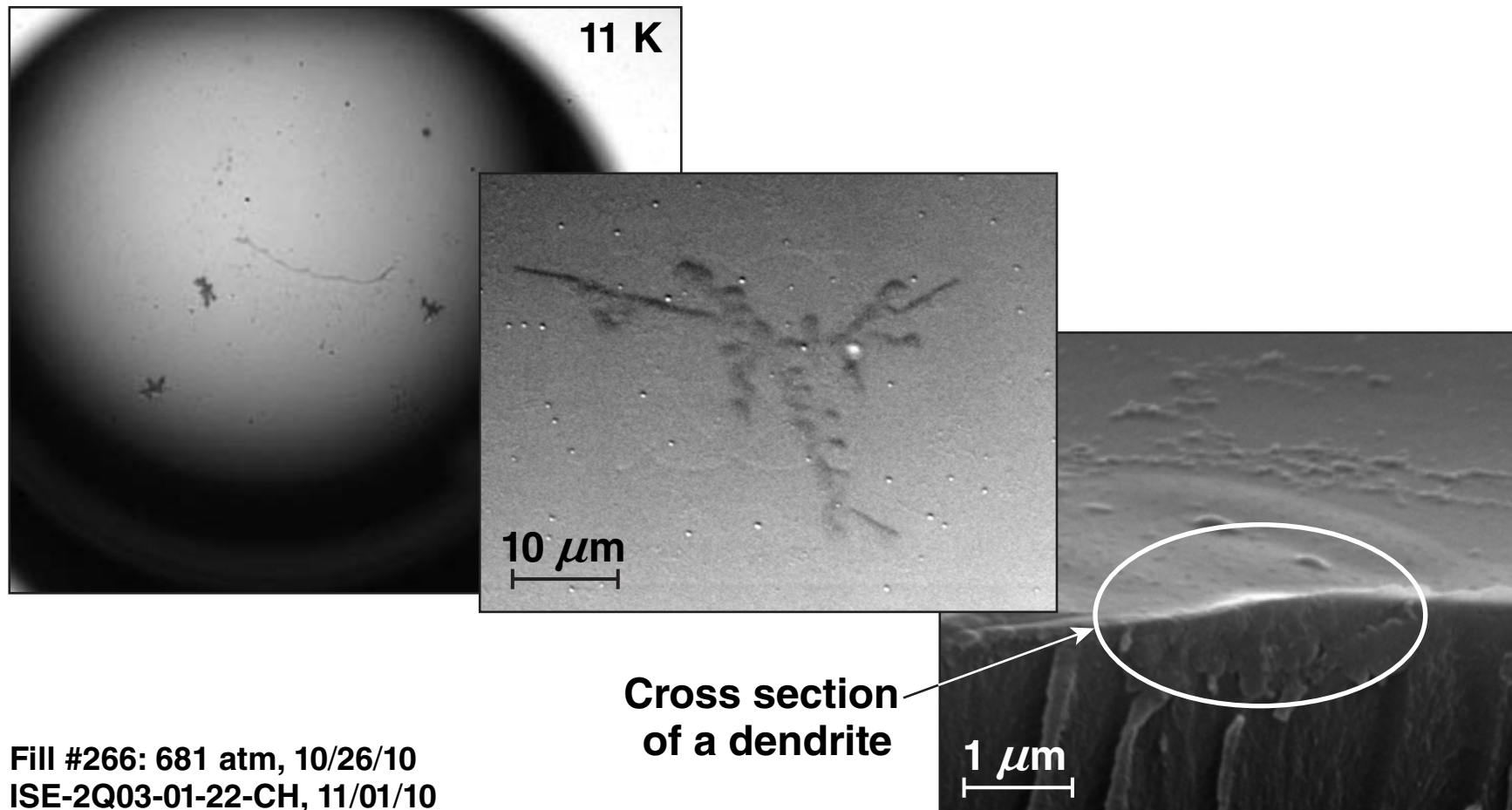


**Post DT-fill defects**

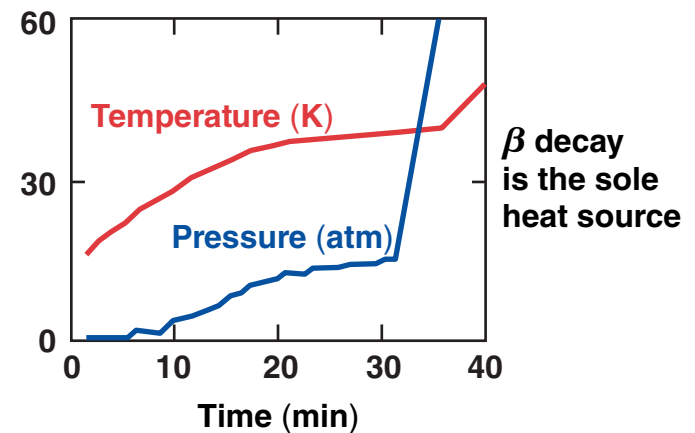
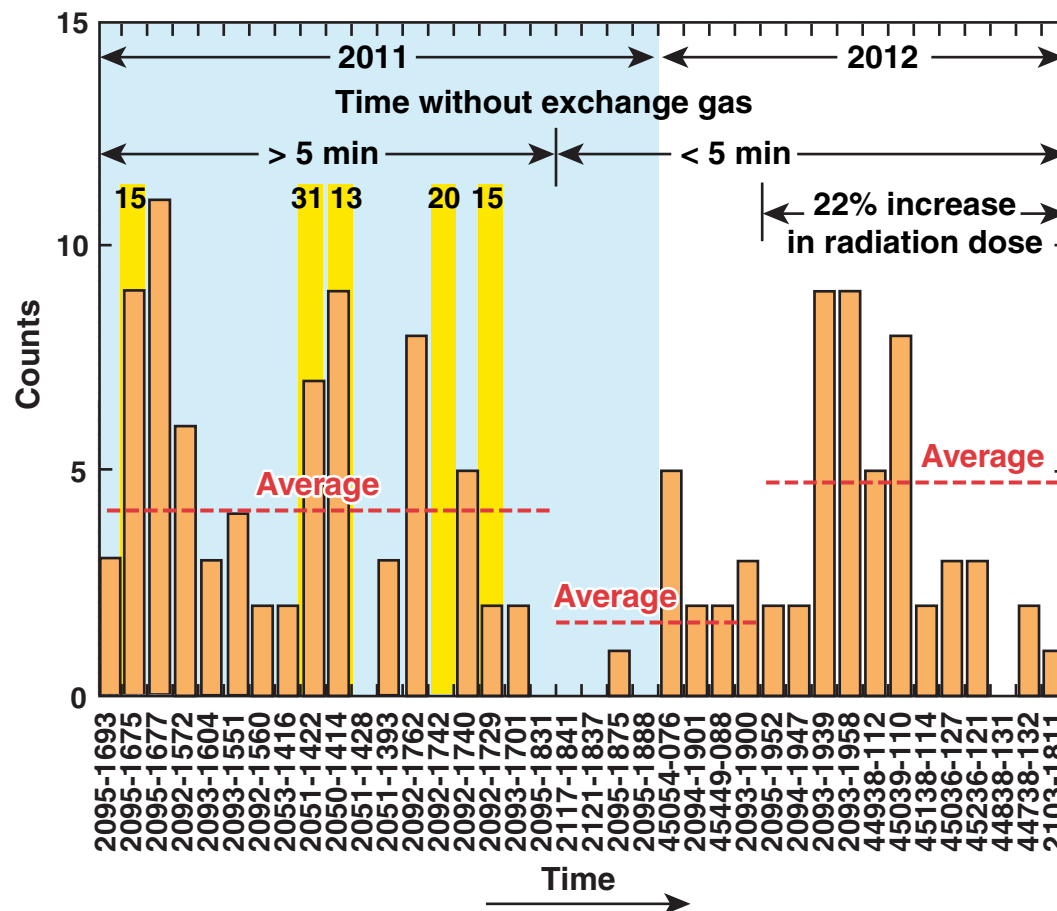
Fill #266  
Cryo-2106-914

**$\beta$  damage and induced stress are needed to form dendrites.**

# Radiation-induced swelling forms dendrites in the inner surface

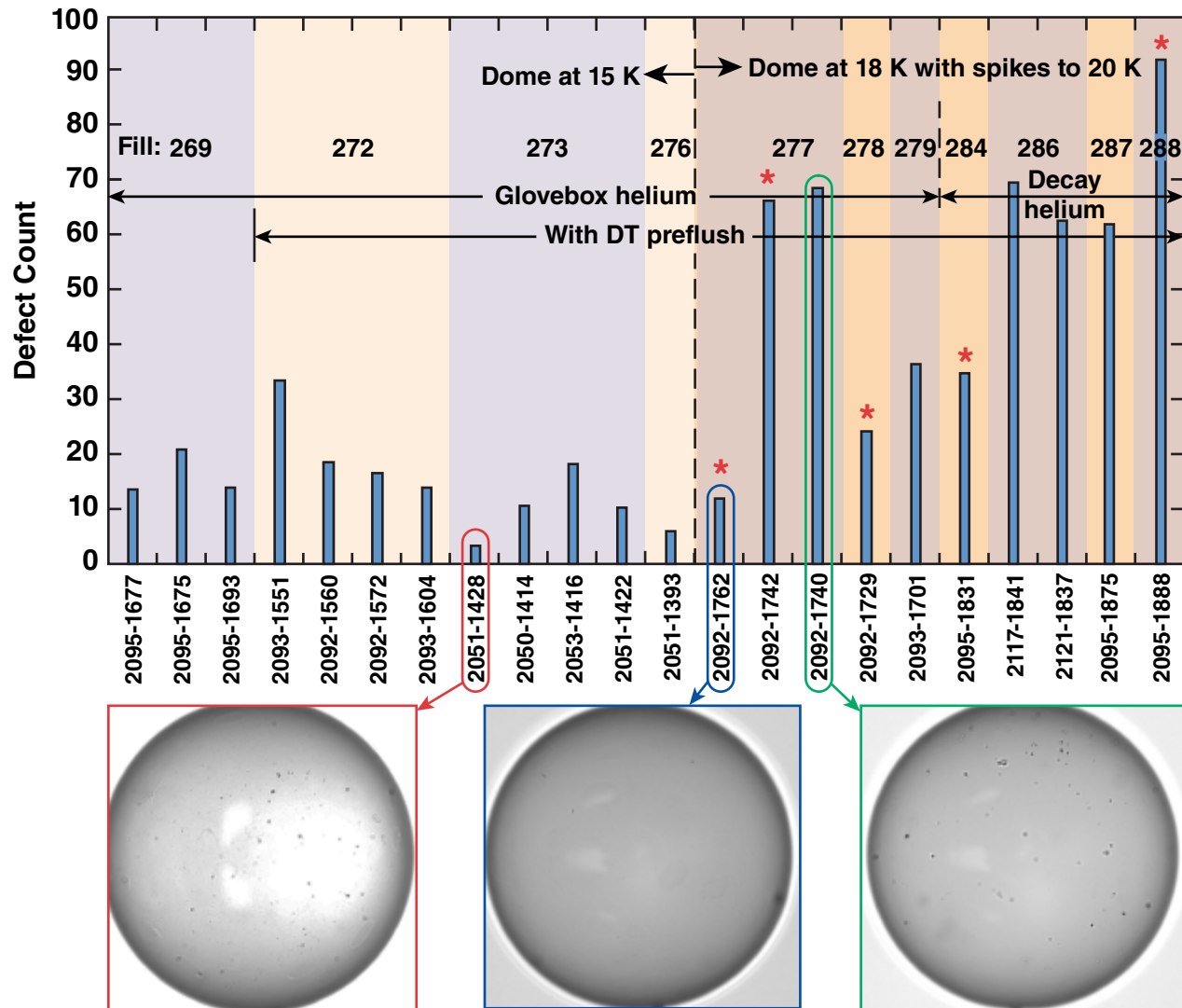


# Dendrite formation most likely occurs when the target warms up during a transfer



36 K radiation heat load  
( $\epsilon = 1$ )  $\approx 1/10 \times \beta$  decay  
heat source

# There is no correlation between defects in the $20\text{-}\mu\text{m}^2$ to $140\text{-}\mu\text{m}^2$ range and neutron yield



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